Appendix B. Landslide Terminology

This Appendix B, Landslide Terminology, is included only for informational purposes and for the convenience of the reader. No portion of Appendix B shall be considered enforceable.

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B.1 LANDSLIDE CLASSIFICATION

The landslide terminology presented here is based on Cruden and Varnes (1996) and DMG (1997) with minor modifications to suit the conditions present on Simpson timberlands. Modifications were necessary to distinguish between rapid shallow-seated landslide features and relatively slow moving deep-seated landslide features.

B.1.1 Shallow-Seated Landslides

Most natural shallow landslides are triggered by elevated pore water pressures resulting from combinations of high intensity and long duration rainfall or from being undercut by stream erosion. The occurrence of high ground accelerations resulting from earthquakes on nearby faults may also result in shallow slope failures either directly or indirectly by reducing soil strength and altering the groundwater regime. In many managed watersheds, thick, over-steepened road fill associated with pre-Forest Practice Rules roads, skid trails, and landings are a common cause of debris slides.

The following guidelines may be used to identify shallow landslides.

- Unvegetated or slightly vegetated scarps and/or slide mass
- Leaning (jack-strawed) trees or disturbed vegetation
- Opportunistic or pioneering vegetation or timber type
- Sharp topographic expression of scarps
- Localized open ground cracks or fresh scarps
- Hummocky or benched topography of slide mass
- Offset or downdropped road surfaces

B.1.1.1 Debris Slides

Characterized by a process whereby unconsolidated rock, colluvium, and soil have failed rapidly along a relatively shallow failure plane. (See Figure B-1 for illustration). In most instances the depth of failure is less than 10 feet. In some instances, however, a debris slide may extend much deeper and incorporate some of the underlying competent bedrock. Debris slides vary in areal extent, from a few square yards to hundreds or thousands of square yards. Debris slides may exist individually or coalesce to form a larger landslide complex.

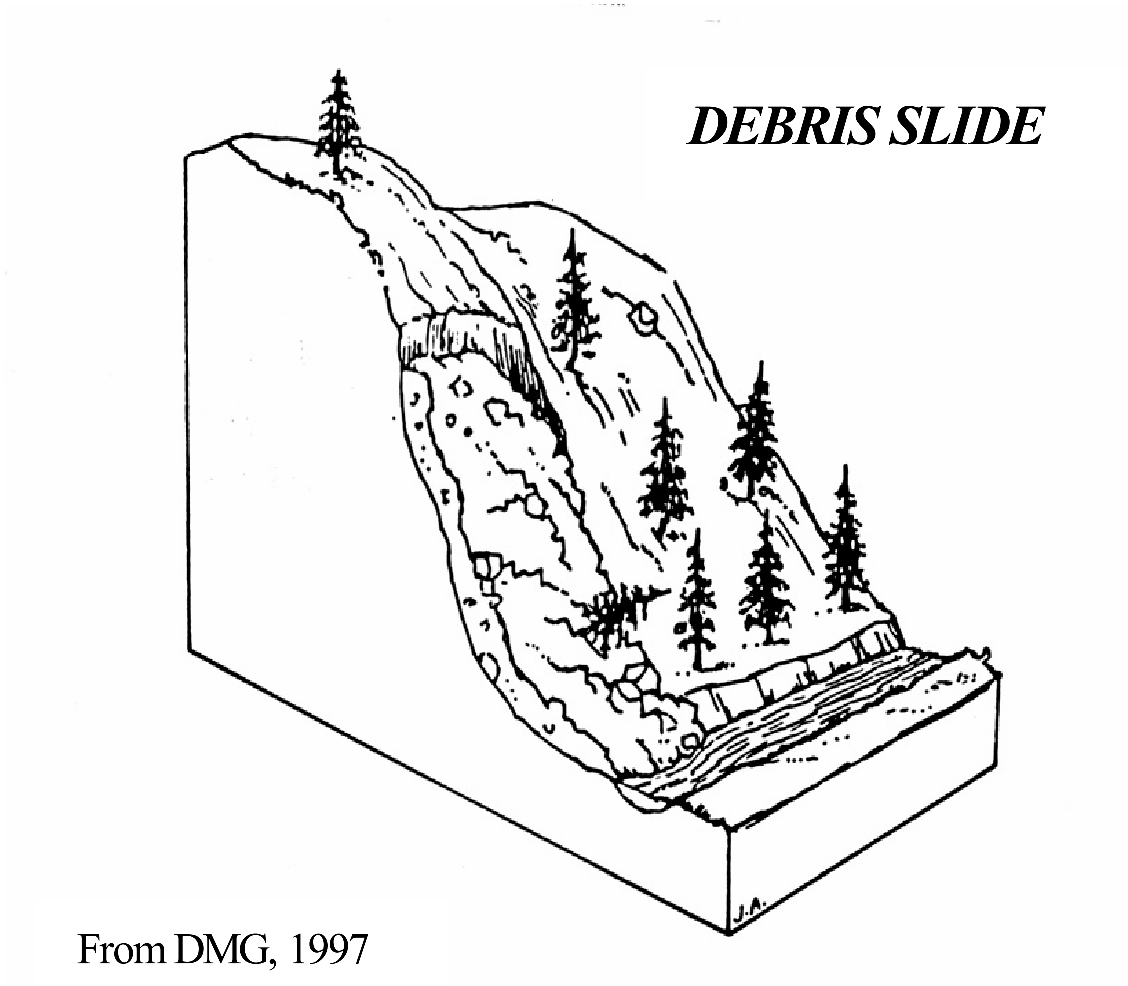


Figure B-1. Debris slide.

Debris slides often form steep, unvegetated scars in the head region and irregular, hummocky deposits in the toe region, with generally well-defined lateral scarps or side boundaries. Slide scarps often continue to ravel for several years following initial failure. Slide debris often overrides the ground surface at the toe. A debris slide deposit may or may not be subject to further movement following the original failure, depending on the geologic character of the landslide deposit and the underlying slope.

B.1.1.2 Debris Flows/Torrents

Debris flows are similar to debris slides, except that debris flows may contain more water and move in a more fluid manner than debris slides. (See Figure B-2 for illustration.) Debris torrents may begin as debris slides or debris flows but become channelized in streams and move rapidly downstream. Debris flows generally do not travel beyond the hillslope on which they originate whereas debris torrents are characterized by long stretches of bare soil and generally unstable channel banks that have been scoured by the rapid movement of debris. As a debris torrent moves through first and second order channels, the volume of material may increase to a much greater size than the initial failure.

B.1.1.3 Channel Bank Failures

Channel bank failures are defined as small shallow debris slides that occur along the banks of stream channels. Such failures are a result of undercutting of the stream bank by stream incision or stream widening. Large channel bank failures that extend far up an adjacent hillslope may become difficult to distinguish from debris slides. Because such failures are relatively common along streams they may be classified separately from the other failures.

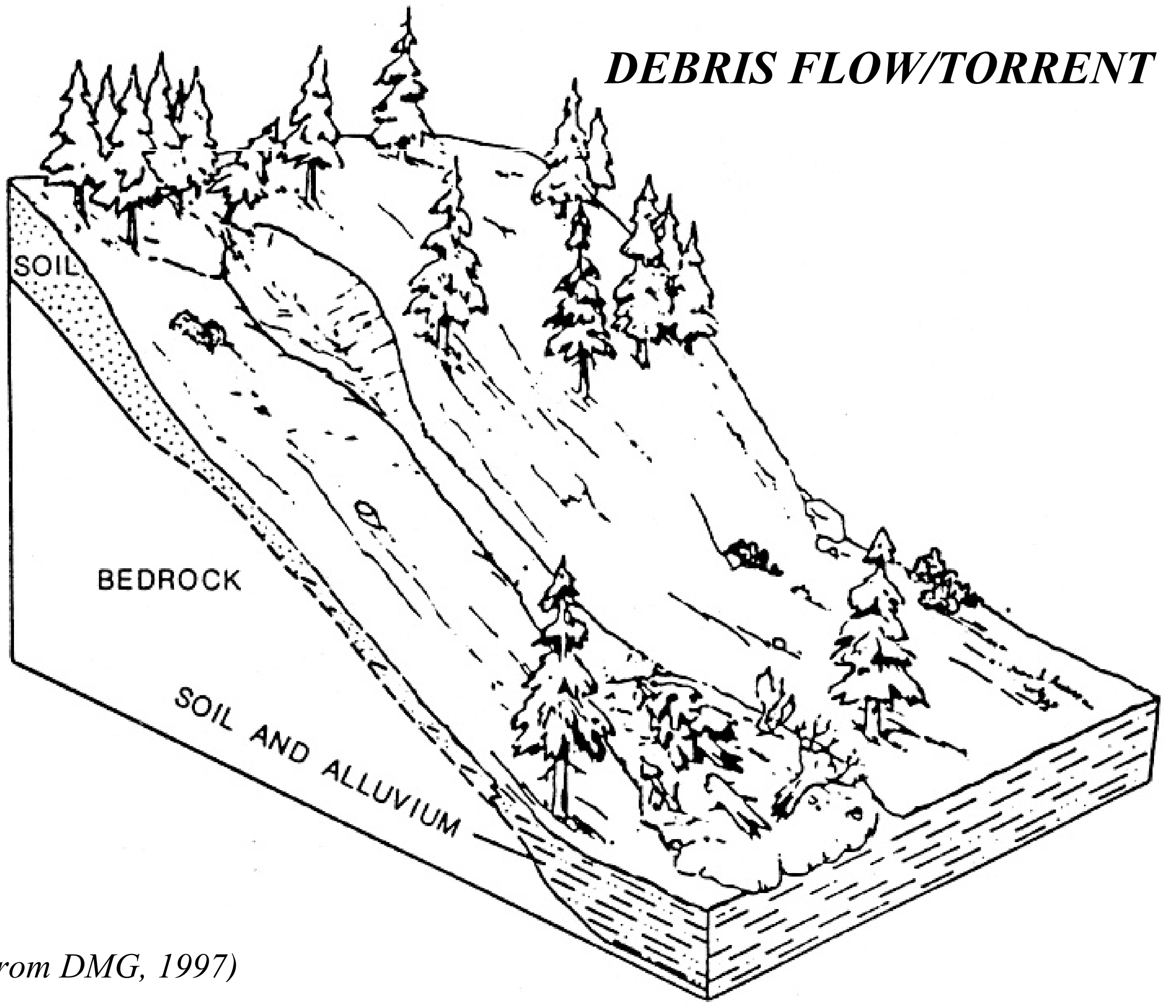
B.1.1.4 Rock Falls

Characterized by catastrophic failure of relatively steep rock slopes or cliff along a surface where little or no shear displacement takes place. Generally rock debris accumulates at the toe of the slope. Rock falls are relatively uncommon in the planning area.

B.1.2 Deep-Seated Landslides

B.1.2.1 Translation/Rotational Rock Slide

Translational/rotational rockslides are characterized by movement of a relatively intact slide mass above a failure plane that is relatively deep when compared to that of a debris slide. The slide plane typically extends below the colluvial layer into the underlying and more competent bedrock. Most slides have a distinct toe at the base of the hillside and undercutting of the toe of the slope by streams is a key factor in their long-term stability. (See Figure B-3 for illustration.)



(From DMG, 1997)

Figure B-2. Debris flow/torrent.

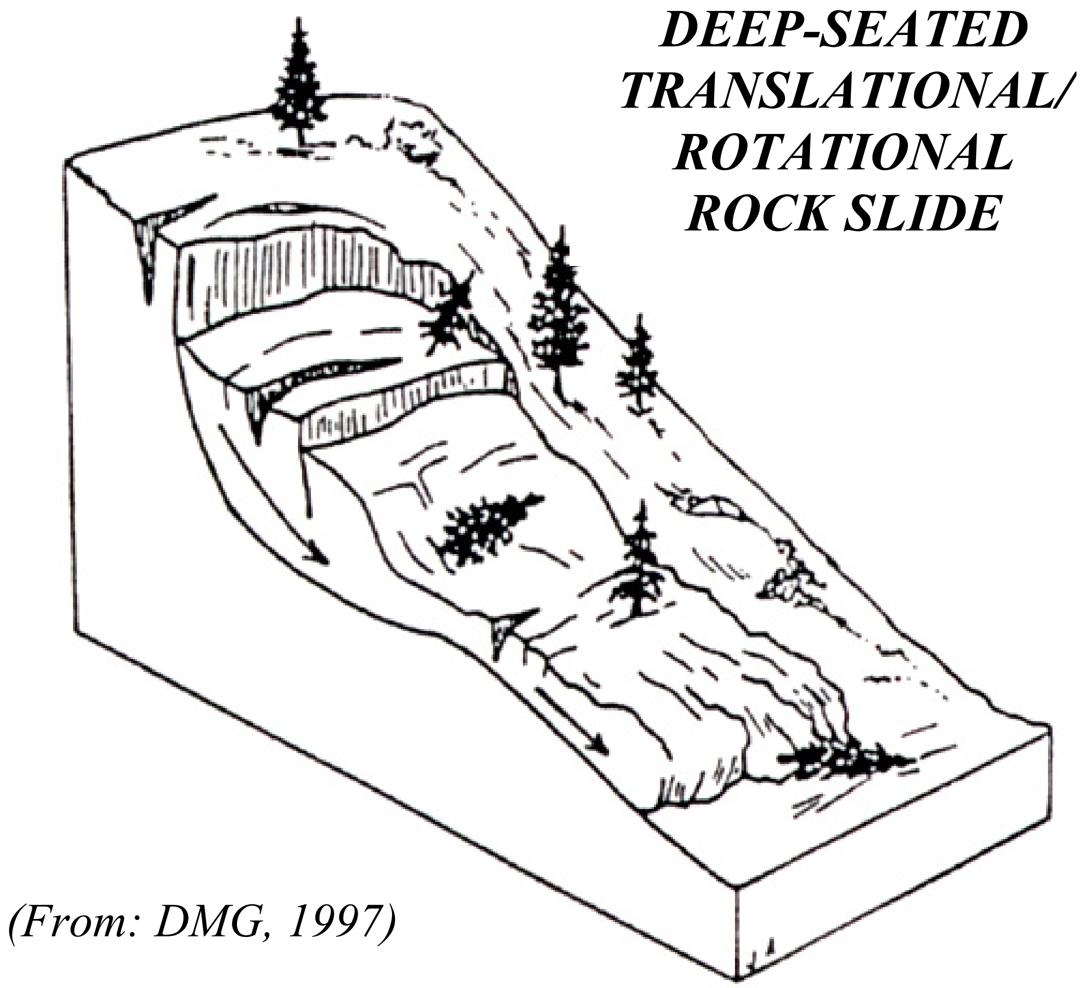


Figure B-3. Deep-seated transitional/rotational rock slide.

Many deep-seated translational landslides on Simpson lands exceed 10-acres, and have a failure plane extending 30' or more into bedrock (although they may be smaller and less deep). Failure can be planar (translational) or curved (rotational). Composite versions involving rotational heads with translation or earthflow downslope are quite common. Translational slides are commonly structurally controlled by surfaces of weakness such as bedding planes, joints, and faults.

Translational/rotational rock slides are identified by a broad arcuate headscarp and a series of mid-slope benches on what is otherwise moderately to steeply sloping terrain. Sag ponds, hummocky topography, and springs and patches of wet ground, as well as opportunistic and pioneering vegetation, such as alder tree, may be present. Commonly the landslide consists of several smaller slide blocks that coalesced together to form the larger landslide complex. Lateral scarps between the individual landslide blocks are often poorly defined, in part due to the low rate and/or infrequent movement of the slide mass. Differential movement between individual slide blocks is common. Where slide movement is most active, drainage networks and stream channels are shallow and generally poorly to moderately defined. Movement is most apparent in the upper portion of the hillside and less apparent near the toe. Steep main scarps, secondary internal slide scarps, and toe slopes may be subject to debris sliding.

Most deep-seated translational/rotational landslides tend to fail incrementally, rather than in the catastrophic manner of a shallow landslide. Recent research provides a basis for the incremental movement of deep landslides (Iverson 2000). Movement is usually triggered by cumulative rainfall over long periods, usually on the order of weeks to years (Miller 1998; Reid 1994) or by high ground accelerations experienced during large magnitude earthquakes (Keefer, 1994). Although rockslides can be triggered by prolonged rainfall, usually on the order of weeks or months, many deep-seated landslides may only be activated during large earthquakes. In seismically active regions, it is quite likely that high ground accelerations experienced during seismic shaking is the dominant mechanism for initiating movement on large-scale landslides.

B.1.2.2 Earthflows

Earthflows are characterized by a relatively large semi-viscous and highly plastic mass resulting in a slow flowage of saturated earth. Most earthflows are comprised of a heterogeneous mixture of fine-grained soils and rock. Earthflows may range from less than one acre to hundreds of acres. The depth of failure is varied but typically greater than 15 feet. Even though most earthflows are relatively shallow features, (in comparison to translational/ rotational landslides) earthflows are classified as a “Deep-Seated Landslide“ because they tend to be more closely related to a slow and infrequent moving Translational/ Rotational landslide than a shallow rapid debris slide or debris flow. (See Figures B-4 and B-5 for illustrations.)

Earthflows are identified by irregular and hummocky ground. Drainages are often shallow, irregular and poorly defined. Active bank erosion and gullying is common on the more active earthflows. An arcuate headscarp may be absent. Sag ponds, springs and patches of wet ground may be present. Commonly the lateral margins of slides are bounded by swales or stream channels. In the aerial photographs, such slides may have a “deflated” appearance”. Many earthflows occur on gentle to moderate grassland areas barren of conifers.

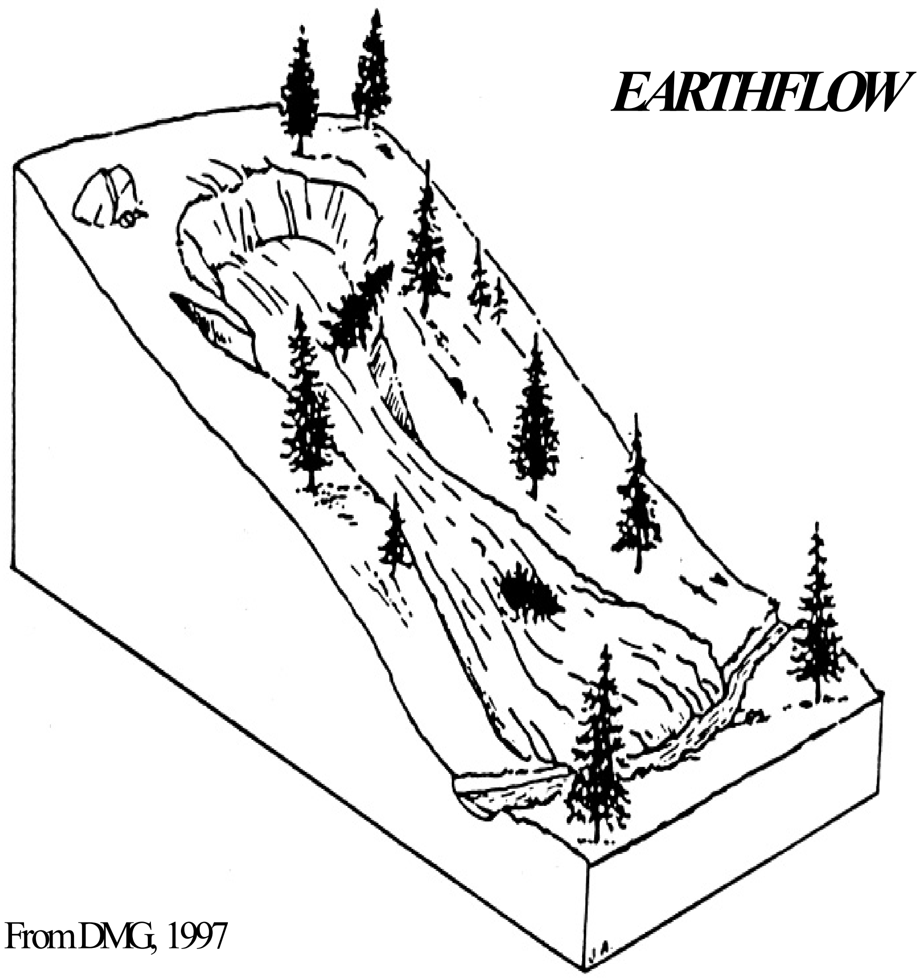
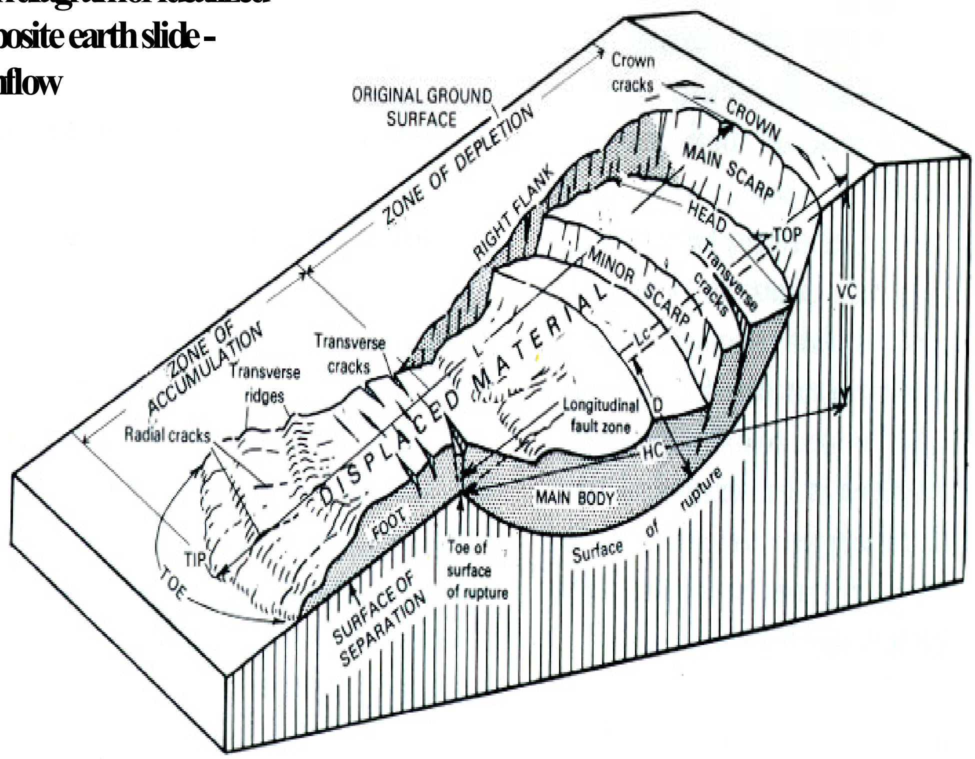


Figure B-4. Earthflow.

Block diagram of idealized composite earth slide - earthflow



From Varnes, 1978).

Figure B-5. Block diagram of idealized composite earthslide/earthflow.

Degree of activity also varies. Many earthflows are dormant while others exhibit seasonal creep in response to high rainfall. Rapid movement of such failures is rare. Ground displacement is generally slight, and catastrophic failure of the slope is unlikely. Slide materials commonly erode easily, resulting in gullying and irregular drainage patterns. Reactivation of the slide mass is likely in response to removal of toe support, high rainfall events and by large seismic events. Because of the seasonal movement associated with some of these slides, they are often unable to support forest stands.

B.2 LANDSLIDE ACTIVITY CRITERIA

Terms related to slide activity and age are described below. The terminology has been modified from [Cruden 1996 #152] to more accurately address specific concerns of timberland management. Landslide age and activity are categorized different for shallow landslides, which typically fail catastrophically, compared to deep-seated landslides, which are characteristically incremental reactivations of preexisting slides.

Shallow landslides tend to fail catastrophically in a single event and then degrade and revegetate. They become indistinguishable over a short time period (geologically speaking) and are categorized by age (time since failure). Deep-seated landslides, which typically move incrementally over a much longer time period compared to a shallow failure, are categorized by their geomorphic expression and inferred level of activity. Because such slides move very slow and incrementally, determining the absolute age of a deep-seated slide is generally not feasible.

Table B-1. Landslide age/activity definitions.

SHALLOW SEATED LANDSLIDES	
Active	Currently moving
Recent	Movement within past 5 years
Historical	Movement within past 50 to 100 years
Old	Greater than 50 to 100 years old
DEEP-SEATED LANDSLIDES	
Active to Recent	Movement within past 5 years
Historically Active	Movement within past 50 to 100 years. Sharp geomorphic expression of the slide; Recent or on-going slide movement.).
Dormant Young	Relatively youthful geomorphic expression of the slide. Slide movement is typically very slow and episodic. Slide is not active but the potential for still exists.
Dormant Mature -	Mature and subdued expression of the slide. Rate of slide movement is extremely slow. These slides likely developed under different geomorphic or climatic conditions, or are seismically triggered. Slide is not active but the potential for activity still exists.
GENERAL	
Dormant	Slide that is not presently active but potential for activity still exists.
Relic	A slide that is not active and for which, the driving mechanism or climatic conditions no longer exist

B.3 LANDSLIDE PRONE TERRAIN

Minimizing future sediment production from harvest activities requires the identification of potential unstable slopes where future landslides might be expected to occur. The delineation of landslide prone terrain is tailored to shallow failures (e.g. debris slides and debris flows) since most deep-seated landslides are reactivations of pre-existing slides.

In general, steep slopes, inner gorge slopes, steep headwall swales, and breaks-in-slopes have been identified as being potentially high risk areas for producing shallow landslides compared to adjacent slopes (REF). (See Figure B-6 for illustration.)

The physical parameters that increase the potential of shallow slope failures include:

- Steepness of slope.
- Slope Form
- Soil strength and geologic structure
- Saturation of the ground leading to elevated pore water pressures, seepage pressures, and/or hydrostatic loading of the slope.
- Removal of toe support by grading or stream incision.
- Improper road construction and maintenance (e.g. surcharge loading of the road fill, diverted and concentrated runoff, and removal of toe support)
- Modification of the vegetative canopy (e.g. reducing root strength reinforcement, temporarily increasing water inputs and soil moisture because of reduced evapotranspiration).

The identification of higher and lower hazard areas is based primarily on slope gradient, slope form and underlying geology. Slope gradient is the dominant factor influencing shallow slope failure. Not surprisingly, the steeper the hillside, the greater the landslide hazard. Landslides can occur anywhere across the landscape but tend to be most common on slopes steeper than about 70%.

Landslides are also more frequent in areas of convergent slope form where surface and ground waters tend to concentrate and where colluvial soils tend to be thickest.

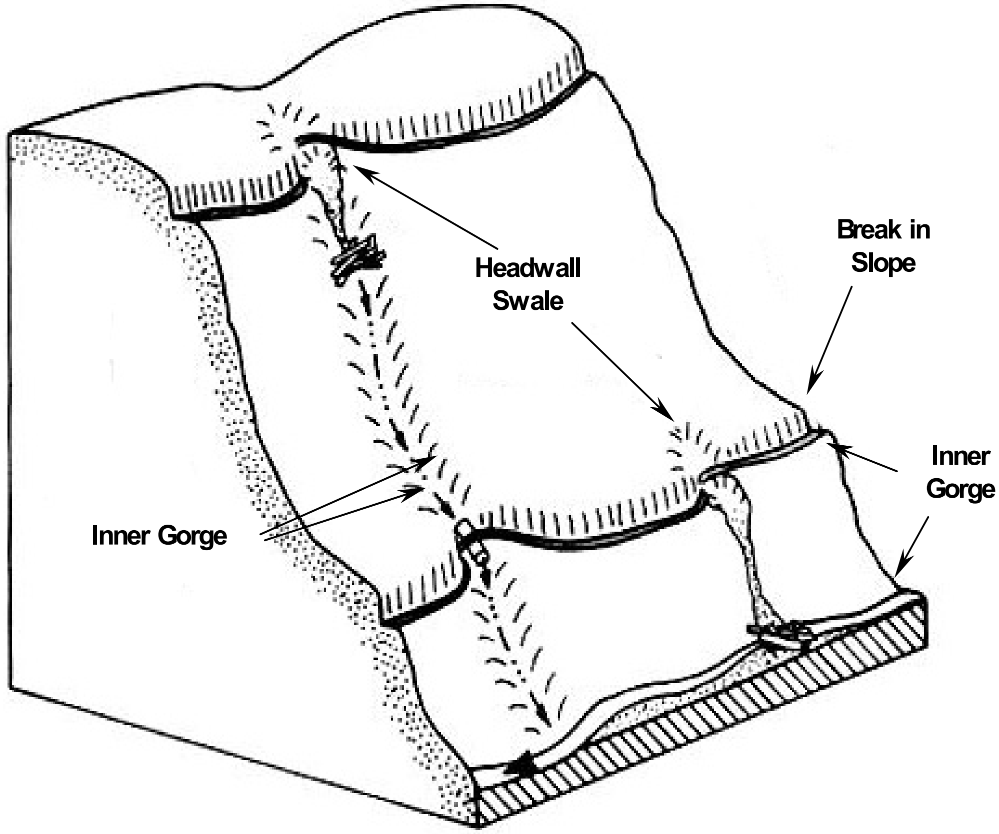


Figure B-6. Features of landslide prone terrain.

B.3.1 Inner Gorge/Steep Streamside Slope

Inner Gorges and Steep Streamside Slopes, from a forestry perspective, are characterized by narrow, steep slopes located immediately adjacent to a stream channel formed by coalescing scars from shallow landsliding and stream erosion. Slopes descend directly to streams without significant intervening topographic benches. Slope gradients are typically greater than 70%, dependent upon strength and structural characteristics of the underlying bedrock materials. (See Figure B-7 for illustration.) An **Inner Gorge** is where a more-or-less distinct break in slope separates steeper "Inner Gorge" slopes below from lesser gradient slopes above. In some instances, a distinct break-in-slope is absent. Where the break-in-slope is absent but slopes are steep and historic landslide processes (<50 - 100 years old) are present, the slope is referred to as a "**Steep Streamside Slope**". In the case of a Steep Toe Slope the upslope limit of the unit is somewhat subjective and based primarily on incidence of historical landslides and professional judgment.

Inner gorge/Steep Streamside Slopes may contain inclusions of less steep areas or divergent slope areas that are more stable than the surrounding landscape. The risk of failures is greatest where shallow, permeable, non-cohesive soils and colluvium overlie relatively impermeable bedrock, in areas of convergent topography, and where the toe slope is actively being undercut by stream bank erosion, particularly on the outside edge of stream bends. The hazard is also relatively high along the toe of dormant or active deep-seated translational landslides. Where bedrock is exposed, the inner gorge or steep streamside slope may be relatively stable. Existing slides, springs, tension cracks, old slide scarps, leaning trees, active bank erosion, and poorly defined drainages are also indicators of more unstable slopes. Identifying exact locations of future slides may be difficult due to permeability contrasts in underlying bedrock.

A "potentially active" inner gorge or steep streamside slope is where there is a relatively high incidence of historic (<40 years) non-road or skid trail related shallow landslides (debris slides, debris flows) on or adjacent to the area of concern. A dormant or inactive inner gorge is where recent or historic landslides are not present.

Inner gorge and steep streamside slope activity can be based on field reconnaissance and review of historical sets of stereo aerial photographs. The review should include at least one stereo of photos taken shortly after a major storm (e.g. 1964, 1972, 1996). The area reviewed should be sufficiently large enough (i.e. 1000s-of-acres) that a rough pattern of landslide processes can be established. The area reviewed should also have similar topographic, geologic and hydrologic characteristics.

B.3.2 Headwall Swales

Headwall swales and debris slide slopes are characterized by narrow, steep convergent topography (swales or hollows) located at the heads and upslope of Class 3 watercourses that have been sculpted over geologic time by repeated debris slide and debris flow events. Slopes gradients are generally greater than 70%. Slopes are often smooth to slightly irregular, unbroken by benches.

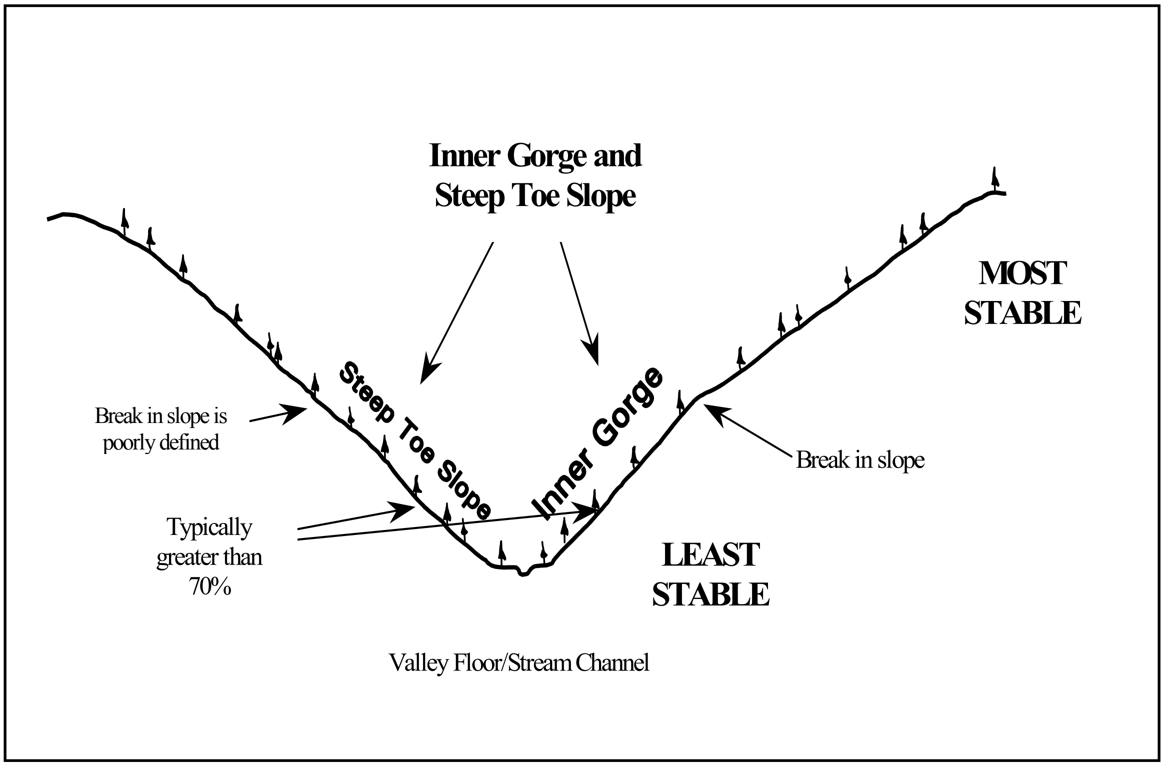


Figure B-7. Inner gorge/steep streamside slope.

Swales often have a teardrop or spoon shape appearance. Seasonal seeps, springs and wet areas may exist within the axis of the swale toward the base. The soil and colluvium depth is often much deeper within the axis of the swale than on the adjoining side slopes. The surface expression of the swale may be distinct to subdued. The width of the unit is highly variable ranging between 30 and 100 feet. Many headwall swale areas can be identified using SHALSTAB.

Failure may occur within the axis of the swale or on the steeper sideslopes leading into the swale. The risk of failure is tends to be greater where there is a moderately thick pocket of loose, cohesionless soils mantling relatively impermeable bedrock. A driving force behind failure is the concentration of perched groundwater into the axis of the swale. Sharp “V” shaped swales or swales where bedrock is exposed have a relatively lower risk of failures.

Not all headwall swales have the same potential for failure. Generally, risk of landsliding is greater in headwall swales where past shallow landsliding in similar adjacent swales has occurred. Hence, the slide history of nearby headwall swales can be used to help identify unfailed high-risk swales. This is not to say that an isolated unfailed headwall swale is stable, but rather that from an empirical standpoint, the risk of failure is generally greater where other similar swales have failed. Swales entering into narrow and steep gradient channels have a higher potential for generating debris lows and torrents.